AP Biology

Unit 2.1 – Bioenergetics

Notes & Practice Exam

Contents

Section 1 – Energy Dynamics

1.1 – How is energy defined & described biologically?

A fundamental characteristic of living things is the acquisition & transformation of energy. The mechanisms underlying these actions can be used to classify organisms as we will study in future sections. For now we will define **energy** as the capacity to perform work and is measured in units such as kilocalories (kcal) or Joules (J). The two basic forms of energy are **potential energy**, the energy possessed due to location or arrangement of objects, and **kinetic energy**, the energy due to motion of objects. An important example of potential energy is the bonds holding together molecules: as bonds change, electrons move closer or further from each other making a molecule more or less stable. When potential energy is converted to kinetic energy, actions can occur such as chromosomes moving apart during mitosis, locomotion in animals & molecules splitting during digestion. When a process is described in terms of energy, it will either require energy or release energy. Reactions that have a net release or loss of energy are called **exergonic**; reactions that have a net gain or requirement of energy are called **endergonic**.

1.2 – What is the biological relevance of the 1st law of thermodynamics?

The **1st law of thermodynamics** states that energy is neither created nor destroyed, only transformed or transferred. When molecules absorb energy, such as pigments absorbing solar energy, this is a transfer & transformation of energy forms. Solar energy causes bond electrons (potential-chemical energy) in pigment molecules to move (kinetic energy) & be transferred to enzymes, providing them with higher potential energy to produce ATP for photosynthesis. The chemical energy stored in the bonds of foods (carbohydrates, fats, etc.) is transferred to numerous molecules in a series of reactions during cellular respiration. As molecules absorb energy, their electrons can shift to produce forms that are more energetic due to bond types and arrangements. For example, cellular respiration causes electrons in glucose to transfer to NAD+, making it highly energetic & primed to help make ATP. A major consequence of the 1st law is that organisms must have a constant supply of energy or materials to extract energy from and if energy demands exceed energy consumption, death ultimately results.

1.3 – What is the biological relevance of the 2nd law of thermodynamics?

The **2nd law of thermodynamics** states that all matter tends to become disordered. Another way to think about this is that materials usually break down or decompose spontaneously instead of magically self-assembling into complex structures. A great example is the DNA double-helix's structure: very complex & made of a variety of atoms in a specific order. It shouldn't come as a surprise that DNA doesn't form spontaneously; it needs enzymes & ATP energy to be synthesized in a complex series of events. Conversely, the ATP molecule's bonds are highly energetic, which is a direct consequence of its bond configurations that also make it an extremely unstable molecule that transforms into a more stable form spontaneously.

1.4 – How does the free energy equation link the laws of thermodynamics?

The **free energy equation** is written as $\Delta G = \Delta H - T\Delta S$, where **G** is a variable called free energy, **H** is a variable called enthalpy, and **S** is a variable called entropy. The "triangle" is the Greek letter Delta and means "change in". T is for temperature, usually measured in Kelvin scale and in biological temperature ranges.

ΔH, the **enthalpy** change, tells us if the average of all reactions in a process released energy or required energy. Enthalpy measures the energy of substances and can be measured, for example, by

light intensity (solar energy), temperature (kinetic energy) or bond energies (chemical energy). Food we consume is labeled with calories, meaning there is a certain amount of potential energy in that food. Fats typically have many more calories than carbohydrates due to their extensive amount of bonds and thus electrons available to transfer energy.

ΔS, the **entropy** change, tells us if products become more ordered/unstable or more disordered/stable. **Entropy** measures *disorder*, so positive values will be reactions that produce molecules in a broken down, more stable form; negative values will be reactions that produce very ordered, unstable molecules. Are ordered biomolecules always unstable? They may not be explosively unstable but yes they are always considered less stable than the individual parts they are made of. Entropy is also represented as the *lack of* potential energy for conversion into kinetic energy. This means that molecules which are very stable have already been broken down to a very simple form with limited potential energy remaining to be extracted. In general: Forming substances that are complex & ordered will yield negative values for ΔS (kinetic energy is probably needed to do the reaction), but producing stable & disordered molecules will yield positive values for ΔS (kinetic energy is probably produced from the reaction).

When taken together, the equation components show how the energy, stability & complexity of molecules decide how they will change during biochemical reactions. If the ΔG result is positive, the process is non-spontaneous and requires free energy (energy is required from the environment or other molecules). If the ΔG result is negative, the process is spontaneous and gives off free energy (energy is released into the environment or into other molecules).

Section 2 – Energy Sources in Biological Systems

2.1 – What are characteristics of effective energy molecules?

Molecules that have benefited cells by providing more energy than other molecules have undergone natural selection and now serve as the energy molecules for most living things. The most effective ways to provide energy to a substance are by rearranging bonds (electrons) so it becomes unstable, and transferring atoms/groups of atoms so it becomes unstable. The best example of this is the ATP molecule **phosphorylating (FOS-FOUR-ILL-ATING)** other molecules. Another method is the ability to transfer electrons completely. When a substance gains electrons it has been **reduced** and when a substance loses electrons is has been **oxidized**. A mnemonic device to remember this is "**LEO** the lion says **GER**" (**L**ose **E**lectrons **O**xidation/**G**ain **E**lectrons **R**eduction). Remember that electrons are the underlying foundation of bonds and some molecules have been especially good at shuttling electrons between molecules without having their structure compromised. These molecules are called electron carriers. One example is **NAD^+** + H$\leftrightarrow$ **NADH** where electrons from H added to NAD+ form the uncharged molecule NADH and removal of the H revert it back to NAD^+. When NADH is oxidized, its electrons are transferred to other molecules that can then perform work.

2.2 – How does the structure of ATP suit its function?

The structure & **hydrolysis** of **ATP** (p. 149) and cycle of ATP (p. 151) diagrams must be copied into your note outlines; a summary of them follows. ATP (Adenosine Triphosphate) is made of the purine base **adenine**, the sugar **ribose**, and three attached **phosphate groups**. The potential energy of ATP resides in the phosphate groups because they are highly unstable due to repulsive forces between the negative oxygen regions. Imagine trying to force two negative ends of a magnet together; very difficult but it can be done if enough energy is applied. ATP also decomposes spontaneously since it is so unstable, therefore it must be easily recycled. When ATP transfers a phosphate group to another molecule, much of the energy will be lost as heat but some is used to increase the energy of that molecule. ATP is generally used to power endergonic reactions and is produced during exergonic reactions. The details of ATP production will be discussed next.

2.3 What are the Two Mechanisms of ATP Production?

We have already seen that the terminal phosphate bonds are what give ATP its energy characteristic. A very select group of enzymes have evolved to produce ATP & are especially good at positioning ADP + P_i, relieving electrostatic tension so their electrons can interact and form the unstable third phosphate bond. The first mechanism of forming ATP is called **Substrate-Level Phosphorylation (FOS-FOUR-ILL-ATION)**. In this mechanism, some molecule (substrate) already has a phosphate group on it and an enzyme transfers it to ADP, forming ATP. The second mechanism of producing ATP involves a more indirect approach. Energy from oxidation of electron carriers like NADH can be put to work, producing high levels of potential energy to power specific enzymes. These enzymes then attach free P_i (not attached to a molecule, just free as an ion) onto an ADP molecule, producing ATP. This method of ATP production where energy from oxidations indirectly powers ATP production is called **Oxidative Phosphorylation**. Draw the diagram of cellular respiration showing the phases & where ATP is made on p.167.

Section 3 – Cellular Respiration Reactions part 1

3.1 – What is the function of cell respiration?

All life uses ATP as a major energy molecule for most cellular tasks. ATP is highly efficient and matches the energy needs of most cell reactions. A molecule of glucose can produce 686kcal/mol but most steps in cell reactions require about 5kcal/mol on average. If glucose is instead used to produce ATP molecules, these can individually power cell reactions with less waste. Cellular Respiration has evolved to be the most efficient pathway for oxidizing glucose to ultimately produce ATP in cells.

3.2 – Where does cellular respiration take place?

All life makes ATP but not all life has the same pathway to do so. As discussed formerly, **glycolysis** is a metabolic pathway that all life uses and this occurs in the cytoplasm, which all cells have. Glycolysis produces a small quantity of ATP and then the fate of its other products depend on certain factors. For eukaryotes, respiration will usually continue inside the **mitochondria** in the presence of oxygen (**aerobic respiration**); in the absence of oxygen however, **fermentation** in the cytoplasm will complete the process. Prokaryotes in anaerobic environments will use fermentation but if oxygen or other compounds are present, further oxidation of glucose can occur via oxidative phosphorylation on specialized parts of the plasma membrane.

3.3 – How can cellular respiration be measured?

The equation for cellular respiration is: $\mathbf{C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O}$ allowing for us to measure respiration using any of the 4 parts of the equation. Typically it is easiest to measure the amount of oxygen used or the amount of carbon dioxide produced. Even though ATP is produced in respiration, we don't usually write it as part of the equation since the ATP is quickly consumed by other reactions; however, be mindful that ATP production is the main goal.

3.4 – What are the Steps & Important products of Glycolysis?

Glycolysis is the first phase of all respiration processes (p.168-169). Glucose is oxidized and then split into two molecules called **pyruvate**. During these steps about 2 ATP are produced by **substrate-level phosphorylation** and 2 NAD^+ are reduced, picking up electrons from glucose, forming **2 NADH**. If oxygen is present, pyruvate will continue to be oxidized as discussed in the next section. If oxygen is absent, pyruvate will continue through one of two fermentation pathways depending on the organism.

3.5 – What are the steps & important products of Fermentation?

The diagrams of **Alcohol fermentation** & **Lactic Acid fermentation** (p. 178) need to be copied into your note outlines. Alcohol fermentation is used by some bacteria, plants and yeasts important in beer/wine production. The pyruvate from glycolysis is oxidized further into acetaldehyde releasing carbon dioxide, one reason for air bubbles in yeast products like dough. Acetaldehyde is then reduced to **ethanol** while NADH is oxidized back to **NAD+**, making it again available to oxidize more glucose in glycolysis. Lactic Acid fermentation is similar but no carbon dioxide is produced and pyruvate from glycolysis is directly reduced to **lactic acid** by NADH. This also restores **NAD+** as an oxidizing agent for glycolysis again. Because lactic acid is in fact an acid, too much of this pathway can cause chemical damage to cells if the acid builds up too quickly. Animals experience this acid buildup in the form of muscle cramps during strenuous exercise; as we exhaust our cellular oxygen levels, fermentation takes over instead of oxidative phosphorylation. This buildup of lactic acid causes the pH level to drop and the acidic protons cause reactions leading to a "burning" sensation in your muscles.

Section 4 – Cellular Respiration Reactions part 2

4.1 – How does the structure of mitochondria suit their function?

Draw & label the orange mitochondrion diagram on p. 112. **Mitochondria** are double-membrane organelles that maximize surface area. The internal portion has a contained liquid called the **matrix** with many respiratory enzymes and other proteins. The matrix has an ideal **pH** and mixture of chemicals to assure the required oxidation/reduction reactions occur efficiently and aren't interfered with by other molecules. Between the **inner membrane** and the **outer membrane** is the **intermembrane space** that serves as a separation region, which will be essential to oxidative phosphorylation. Finally, the inner membrane is where enzymes that perform essential functions for oxidative phosphorylation are located; with a large folded surface area to contain many enzymes, the folded structure of the inner membrane is ideal for maximizing efficient ATP output.

4.2 – What are the steps & important products of the Krebs cycle?

If oxygen is present in eukaryote cells, respiration will continue aerobically instead of ending with fermentation. The next respiration phase called the Krebs cycle (p.170-171) occurs in the mitochondria **matrix** and begins by transforming pyruvate into acetyl CoA, releasing CO_2 in the process. Each time the Krebs cycle oxidizes organic molecules further, CO_2 is released and the organic molecule therefore loses a carbon atom demonstrating conservation of mass. Although CO_2 is useful in plants, it is generally a waste product in heterotrophs so this cannot be the main product. As the oxidations occur, reductions occur simultaneously and the electrons are gained by NAD^+ forming NADH. A small quantity of ATP (via substrate-level phosphorylation), NADH & another electron carrier called $FADH_2$ are the major products of the Krebs cycle.

4.3 – How does the Electron Transport Chain establish a proton gradient?

NADH & $FADH_2$ transfer their electrons & H^+ to proteins on the **inner membrane** (**IM**). The final protein of the electron transport chain uses the electrons to join oxygen and hydrogen ions together, forming water. While the electron transport proteins accept and then transfer electrons, they are energized enough to translocate the H^+ from the matrix across the **IM** into the intermembrane space. So much H^+ builds up in this region that it generates a **proton (H^+) gradient** (imbalance of a substance on one side of a membrane) giving the H^+ high potential energy to move itself back into the matrix to offset the imbalance between the matrix and the intermembrane space. The intermembrane space is also a very acidic/low pH environment from all the H+, so it is essential to have this separate region in order to establish a proton gradient while protecting other cell parts & the other mitochondria regions from acidic conditions.

4.4 – How does Chemiosmosis Power ATP Synthesis via Oxidative Phosphorylation?

Draw & label the diagram of Oxidative Phosphorylation on p. 175. The H+ now trapped within the intermembrane space cannot cross back to the matrix directly through the membrane since it is charged and the membrane will repel it. A specialized enzyme called **ATP Synthase** serves as a channel that allows H+ to diffuse through it back into the matrix. As the H^+ moves through, ATP synthase harnesses some of the kinetic energy of the flowing H^+ to power its phosphorylation site. This mechanism of using the proton gradient to power the ATP synthase enzyme is called **chemiosmosis**. ATP is produced as ATP synthase attaches free phosphate ions in the matrix with ADP during **oxidative phosphorylation**. Recall that the energy for chemiosmosis came from NADH, which came from oxidizing organic food molecules…hence the name oxidative phosphorylation.

Section 5 – Producers & their Unique Features

5.1 – What differentiates autotrophs & heterotrophs?

All organisms need an energy source & and a material source to maintain & build biomass. Autotrophs & heterotrophs both can use cellular respiration to break down organic material for ATP but how they obtain organic material differs significantly. **Autotrophs** are able to synthesize their own organic molecules from inorganic sources like carbon dioxide. **Heterotrophs** must obtain their organic materials pre-made in forms like sugars & fats. This is why autotrophs are also called **producers** since they produce the organic materials that can be used by heterotrophs.

5.2 – What features allow autotrophs to make organic compounds?

All autotrophs have evolved specialized enzymes that are capable of "fixing" small carbon molecules into complex biomolecules. For example, plants have the enzyme **rubisco** that catalyzes the construction of biomolecules from the carbon atoms in carbon dioxide; heterotrophs are incapable of incorporating inorganic carbon sources into organic ones, but can rearrange preexisting organic compounds.

The energy source used to power the production of organic molecules is also unique among autotrophs. **Chemosynthetic** autotrophs have specialized enzymes that actually extract energy from metals & sometimes toxic gases while **photosynthetic** organisms have specialized pigments & enzymes to utilize the energy from sunlight. The remainder of these notes will focus on the photosynthetic pathway but be aware that chemosynthesis is also a major organic material production pathway, especially in deep-sea habitats where no sunlight penetrates.

5.3 – How does light provide energy for photosynthesis?

Light contains units of energy called **photons** that come in various energy levels. Photons travel in a wave-like pattern, oscillating up and down and the distance between their peaks is known as **wavelength**. Photons with the highest energy have the shortest wavelengths and thus oscillate very fast. Light is also a mixture of many different kinds such as gamma rays, X-rays & UV rays having high energy, visible light with medium energy and Infrared, Microwaves & Radio waves having lower energy. Photosynthesis harnesses photons in the visible light range between 380nm -750nm. Because photons are in motion, their kinetic energy transfers to pigment molecules' electrons to begin a series of reactions that will generate ATP in a similar fashion as in oxidative phosphorylation during cellular respiration. Instead of oxidations providing the energy for a proton gradient, photons provide this energy source; therefore, the ATP production mechanism used to fuel sugar production during photosynthesis is called **photophosphorylation**.

So why are most plants green? Photons in the green light range are actually not useful for plants and are reflected or transmitted through their bodies, rather than absorbed & utilized. It is photons in the ranges of colors that are transmitted to our eyes that we perceive; hence, we see mostly green when we look at plants because they are reflecting that color light. Natural selection has favored organisms that utilize energy the most efficiently and the pigments/enzymes found in most modern plants absorb blue & red light and reflect green & yellow light. Another interesting piece of evidence for the conditions on early Earth are that many ancient bacteria lineages still absorb UV light and green light, which have been evidenced as the prominent light during those early times. With the ability to harness the energy of light, **photosynthesis** allows an organism to use water & carbon dioxide to produce organic material (sugars) & oxygen: **Light + $6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$**

Section 6 – Photosynthesis Reactions part 1

6.1 – How does the structure of Chloroplasts suit their function?

Draw & label the chloroplast diagram (a) on p. 111. **Chloroplasts** are double membrane organelles that maximize surface area. Below the second membrane is a thick fluid called the **stroma** having a very high pH where the Calvin Cycle takes place. Suspended in the stroma are more membrane-bound disc-like structures called **thylakoids** where the Light Reactions take place. This separation of regions in the chloroplast generates microenvironments with ideal conditions for the specific reactions that take place there and membranes allow necessary proton gradients to be established.

6.2 – What is the structure & function of a Photosystem?

Draw & label the photosystem diagram (a) on p.193. Pigments are found on the thylakoid membranes in chloroplasts and often the thylakoids are in stacks called grana, maximizing the surface area for pigments to absorb light. **Chlorophyll *a*** is the main pigment used by plants; this and any other **accessory pigments** in the plant are arranged with special enzymes in clusters called **photosystems**. Each photosystem has a special enzyme **reaction center** that harvests the energy from all associated pigments to start an electron transport chain.

6.3 – How is ATP produced during the light Reactions?

Draw & label the light reactions diagram on p.197. When photons excite pigments, their energy is transferred to reaction center chlorophyll whose electrons are then transferred to the electron acceptor in **photosystem II**. The electron acceptor transfers these electrons to an electron transport chain that will generate ATP by establishing a **proton gradient**: Protons (H^+) from the stroma are translocated into the thylakoid space in the same manner discussed in section 4.3 of cellular respiration. By generating this proton gradient, **chemiosmosis** can generate ATP in the same fashion as discussed in section 4.4 of cellular respiration. Remember that photons are providing the energy for the proton gradient and thus this ATP production method is called **photophosphorylation**. The reaction center chlorophyll lost its electrons to the electron transport chain and thus need to be reduced (re-gain electrons) in order to function again. This task is accomplished when the reaction center chlorophyll splits water, taking the electrons holding the water molecule together, and releasing H+ and oxygen.

6.4 – What other important products are formed during the light reactions?

Recall that the electron transport chain mentioned above is still transporting electrons, but to where? These electrons from the reaction center chlorophyll of photosystem II will end up replacing electrons lost by **Photosystem I**. This photosystem lost its electrons to **NADP+** by another electron transport chain that doesn't produce ATP but does produce the electron carrier NADPH. **NADPH** carries its electrons to the stroma for use in the Calvin cycle.

Many plants can actually divert photosystem I electrons back into the first electron transport chain, in a process known as **cyclic electron flow**. The benefit of this process is that ATP can be generated in excess when needed, especially in intense sunlight and dry conditions that some specialized plants are adapted to. These will be discussed in the next section.

Section 7 – Photosynthesis Reactions part 2

7.1 – What are the steps & products of the Calvin cycle?

As CO_2 enters the stroma, its carbon atom is fused into a pre-existing organic molecule abbreviated RuBP; this phase is called **carbon fixation**. The energy molecules ATP & NADPH are then used to add electrons (reduce) and rearrange the organic molecule into a sugar known as G3P; this is known as the **reduction phase**. Some of this G3P will be exported to be used for the organism's metabolic & growth needs or stored as starch granules. The remainder of the G3P is rearranged using energy from ATP back into the original RuBP molecule; this is known as the **regeneration phase**.

7.2 – How can photosynthesis be summarized?

Draw & label the photosynthesis diagram on p.188. The **light reactions** occur in the thylakoids, produce ATP & NADPH as energy molecules for the Calvin cycle, use water as an electron source and produce oxygen when water is split. The **Calvin cycle** happens in the stroma uses ATP & NADPH from the light reactions along with carbon dioxide to produce organic molecules (sugars) for use in metabolism & growth.

7.3 – What are some Photosynthetic adaptations?

Plants need sunlight but this can also lead to excessively dry or hot conditions. In these conditions pores in leaves called **stomata** allow water & gases to escape the leaves easily which can decrease photosynthesis. In very hot and light intense environments, C4 photosynthesis plants are dominant such as grasses, corn & sugarcane. **C4 plants** have specialized enzymes & cells that keep the Calvin cycle reactions occurring in interior leaf cells where CO_2 cannot escape outward due to high evaporation rates from high heat. Another adaptation is found in **CAM plants** residing in dry areas such as deserts. Most cacti & other succulents are CAM plants that close their stomata during the day and open them at night. While their stomata are open at night, CO_2 is absorbed and incorporated into an organic molecule. During the day when light powers ATP & NADPH production, the CO2 is released into the Calvin cycle from the organic molecule. This ensures the CO2 does not escape during evaporation. Unfortunately, both of these adaptations come with the cost of extra ATP needing to be used for the process. C4 & CAM plants all offset this extra ATP demand by using **cyclic electron flow** as discussed in section 6.4.

A student ran an experiment in which he started with plant seeds. He planted the seeds in well-aerated soil and watered them every day. At day 5 the seed had produced 2 leaves. The student then transported the plant to a very hot location, providing water only once every 2 weeks.

____ 1. Up through day 5, the organelle & process most likely responsible for the organism's energy was
a. Cytoplasm, Fermentation
b. Cytoplasm, Glycolysis
c. Chloroplast, Photosynthesis
d. Mitochondria, Cellular Respiration

____ 2. After day 5, which of the following processes would utilize carbon dioxide
a. Cellular respiration
b. Calvin cycle
c. Oxidative phosphorylation
d. Light-dependent reactions

____ 3. Even though the temperaure & water didn't prove to cause any changes to the metabolic rates of the plant, there was a noticeable and equal decline in photosynthesis & respiration on day 10. Which of the following questions could the student ask to best determine the source of declining metabolism?
a. Was the pH appropriate?
b. Was the plant tall enough?
c. Was the plant short enough?
d. Was the sunlight level appropriate?

____ 4. Which of the following accurately describes the thermodynamics of the plant during its development?
a. ΔH decreased and ΔS increased
b. ΔH increased and ΔS increased
c. ΔH increased and ΔS decreased
d. ΔH decreased and ΔS decreased

____ 5. After the plant was transported to a hot location, how could the student determine if the plant was a C4 or a CAM plant?
a. If the plant had its stomata open during the day it must be a CAM plant.
b. If the plant had its stomata closed during the day it must be a CAM plant.
c. If the plant required more ATP than a C3 plant, it must be a C4 plant.
d. If the plant had a low photorespiration rate, it must be a C4 plant

6. For living organisms, which of the following is an important consequence of the first law of thermodynamics?
A) The energy content of an organism is constant.
B) The organism ultimately must obtain all of the necessary energy for life from its environment.
C) The entropy of an organism decreases with time as the organism grows in complexity.
D) Organisms grow by converting energy into organic matter.
E) Life does not obey the first law of thermodynamics.

7. Why is glycolysis considered to be one of the first metabolic pathways to have evolved?
A) It produces much less ATP than does oxidative phosphorylation.
B) It does not involve organelles or specialized structures, does not require oxygen, and is present in most organisms.
C) It is found in prokaryotic cells but not in eukaryotic cells.
D) It relies on chemiosmosis, which is a metabolic mechanism present only in the first cells' prokaryotic cells.
E) It requires the presence of membrane-enclosed cell organelles found only in eukaryotic cells.

8. The pH of the inner thylakoid space has been measured, as have the pH of the stroma and of the cytosol of a particular plant cell. Which, if any, relationship would you expect to find?
A) The pH within the thylakoid is less than that of the stroma.
B) The pH of the stroma is lower than that of the other two measurements.
C) The pH of the stroma is higher than that of the thylakoid space but lower than that of the cytosol.
D) The pH of the thylakoid space is higher than that anywhere else in the cell.
E) There is no consistent relationship.

Questions 9-10

An experiment to measure the rate of respiration in crickets and mice at 10°C and 25°C was performed using a respirometer, an apparatus that measures changes in gas volume. Respiration was measured in mL of O_2 consumed per gram of organism over several five-minute trials and the following data were obtained.

Organism	Temperature (°C)	Average respiration (mL O_2/g/min)
Mouse	10	0.0518
Mouse	25	0.0321
Cricket	10	0.0013
Cricket	25	0.0038

9. According to the data, the mice at 10 °C demonstrated greater oxygen consumption per gram of tissue than did the mice at 25 °C. This is most likely explained by which of the following statements?

   A. The mice at 10 °C had a higher rate of ATP production than the mice at 25 °C.
   B. The mice at 10 °C had a lower metabolic rate than the mice at 25 °C.
   C. The mice at 25 °C weighed less than the mice at 10 °C.
   D. The mice at 25 °C were more active than the mice at 10 °C.

10. According to the data, the crickets at 25°C have greater oxygen consumption per gram of tissue than do the crickets at 10°C. This trend in oxygen consumption is the opposite of that in the mice. The difference in trends in oxygen consumption among crickets and mice is due to their

   A. relative size
   B. mode of nutrition
   C. mode of internal temperature regulation
   D. mode of ATP production

11. Which of the following describes a metabolic consequence of a shortage of oxygen in muscle cells?

(A) An increase in blood pH due to the accumulation of lactic acid
(B) No ATP production due to the absence of substrate-level phosphorylation
(C) A buildup of lactic acid in the muscle tissue due to fermentation
(D) A decrease in the oxidation of fatty acids due to a shortage of ATP

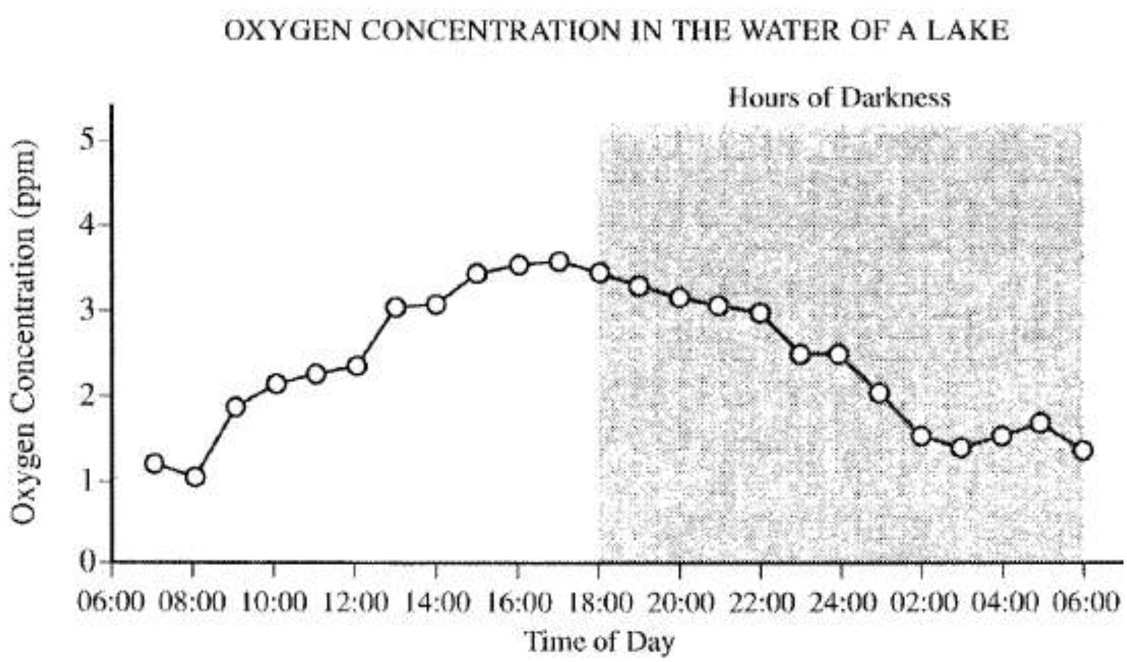
12. Which of the following questions is most relevant to understanding the Calvin cycle?

(A) How does chlorophyll capture light?
(B) How is ATP used in the formation of 3-carbon carbohydrates?
(C) How is $NADP^+$ reduced to NADPH?
(D) How is ATP produced in chemiosmosis?

13. Two nutrient solutions are maintained at the same pH. Actively respiring mitochondria are isolated and placed into each of the two solutions. Oxygen gas is bubbled into one solution. The other solution is depleted of available oxygen. Which of the following best explains why ATP production is greater in the tube with oxygen than in the tube without oxygen?

(A) The rate of proton pumping across the inner mitochondrial membrane is lower in the sample without oxygen.
(B) Electron transport is reduced in the absence of a plasma membrane.
(C) In the absence of oxygen, oxidative phosphorylation produces more ATP than does fermentation.
(D) In the presence of oxygen, glycolysis produces more ATP than in the absence of oxygen.

14.



What most likely causes the trends in oxygen concentration shown in the graph above?

(A) The water becomes colder at night and thus holds more oxygen.
(B) Respiration in most organisms increases at night.
(C) More organisms are respiring at night than during the day.
(D) Photosynthesis produces more oxygen than is consumed by respiration during the day.

Questions 15-19

Photosynthetic activity can be measured using chloroplasts suspended in a buffered solution containing DCPIP, a dye that can accept electrons from the electron transport chain of photosynthesis. Transfer of electrons to DCPIP decreases the relative absorbance of a specific wavelength of light (605 nm) by a solution that contains the dye.

A buffered solution containing chloroplasts and DCPIP was divided equally among six identical samples. The samples were placed at various distances from a lamp, and then all samples were exposed to white light from the lamp for 60 minutes at room temperature. Sample 3 was wrapped in foil to prevent any light from reaching the solution. At 20-minute intervals, the photosynthetic activity in each sample was determined by measuring the relative absorbance of 605 nm light. The results of the experiment are provided below.

		Relative Absorbance of 605 nm Light (arbitrary units)			
Sample	Distance from Lamp (cm)	0 min	20 min	40 min	60 min
1	15	0.89	0.61	0.34	0.04
2	30	0.90	0.67	0.41	0.14
3*	30	0.88	0.87	0.86	0.87
4	45	0.86	0.69	0.47	0.26
5	60	0.92	0.75	0.59	0.41
6	75	0.88	0.79	0.71	0.58
* wrapped in foil					

15. Which of the following provides the best indication that light is required for the activation of electron transfer reactions in chloroplasts?

(A) Calculating the rate of change of the absorbance for sample 1
(B) Comparing the observed results for sample 2 and sample 3
(C) Repeating the entire experimental procedure at night
(D) Including multiple trials for all the samples

16. Which of the following can be reasonably concluded from the experimental results?

(A) Chloroplasts must be suspended in a buffer solution to function properly.
(B) The optimal temperature for activation of electron transfer is 25°C.
(C) DCPIP inhibits biochemical reactions in suspended chloroplasts.
(D) Light from a lamp can substitute for sunlight in stimulating chloroplast processes.

17. If an additional sample containing the chloroplast/DCPIP solution was placed at a distance of 90 cm from the lamp, which of the following predictions would be most consistent with the experimental results?

(A) The concentration of DCPIP in the solution will increase exponentially.
(B) The absorbance at 60 minutes will be roughly equal to 1.4.
(C) The change in absorbance over time in the solution will be less than that of the other samples.
(D) The temperature of the solution will exceed 75°C.

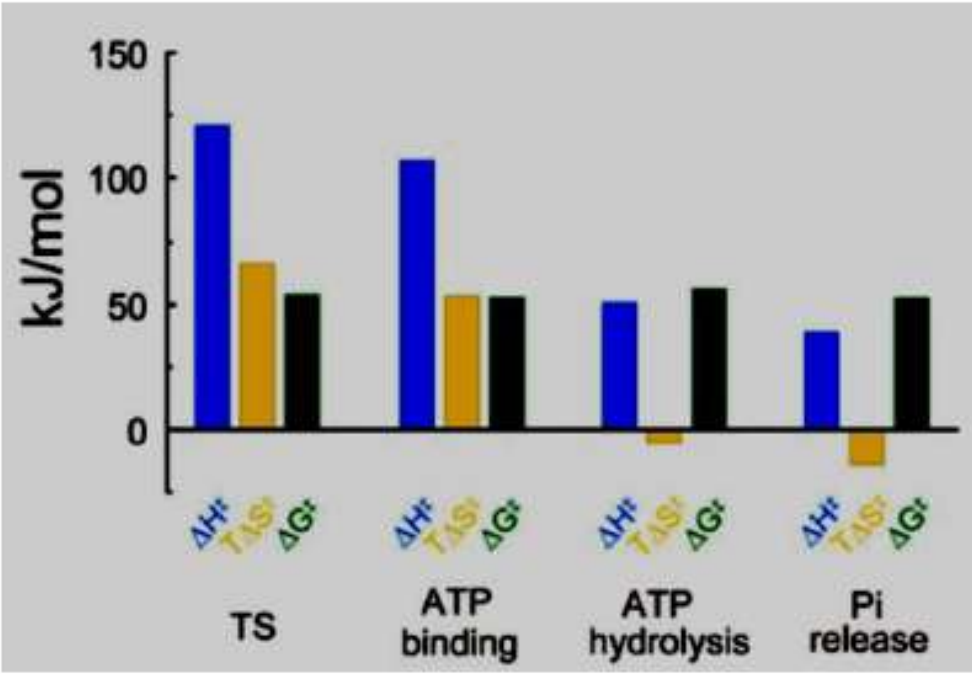
18. Which of the following descriptions of photosynthesis best explains the results of the experiment?

(A) Availability of electrons for transfer to DCPIP depends on light energy.
(B) Movement of DCPIP across chloroplast membranes occurs in less than 60 minutes.
(C) Chlorophyll molecules degrade rapidly in the presence of DCPIP.
(D) DCPIP can only be used to measure photosynthetic activity at low light levels.

19. Which of the following scientific questions could be investigated using a similar experimental setup?

(A) How much carbon dioxide is required by a plant cell to produce one molecule of glucose?
(B) What wavelength of light best activates electron transfer reactions in chloroplasts?
(C) Which molecule in chloroplasts accepts activated electrons from DCPIP during photosynthesis?
(D) Are the same genes that are expressed in chloroplasts also expressed in mitochondria?

20.



An ATPase enzyme functions by rotating like a wind turbine, passing its energy off to another reaction. During a full rotation of the enzyme, each 1/4 turn represents a step to eventually break apart ATP into ADP + Pi. These 4 steps are shown in the figure above, represented by TS, ATP Binding, ATP Hydrolysis, & Pi Release.

a. **Calculate** the minimum amount of free energy required for a full rotation of the ATPase.
b. **Provide reasoning** for why the ATP Binding step & the Pi Release step have similar ΔG values but very different ΔH & $T\Delta S$ values.
c. **Describe** how the **mechanism** of ATP production needed for this reaction would be different in an anaerobic bacterium versus a plant cell.
d. **Identify** ONE use of ATP during the Calvin cycle.

21.

In a certain prairie community, a dominant prairie grass species has recently been infected with a virus that disrupts one of the electron transport proteins in the chloroplasts of infected grass cells.

(a) **Describe** the most likely effects on cellular processes, being SPECIFIC as to which processes and molecules are most likely to be directly affected.

(b) **Predict** the long-term effects on the infected plant populations and their communities. **Justify** your prediction.

(c) In this grass species, 1 mole of glucose can be used to produce 200 ATP. **Identify the cell process** in which this occurs and **calculate the efficiency** of the transformation if 1 mole of glucose contains 385 kcal/mol and 1 ATP contains 9kcal/mol.

22.

DRY MASS OF CORN SEEDLINGS GROWN UNDER DIFFERENT CONDITIONS

Treatment Group	Treatment	Initial Dry Mass of 10 Plants (g)	Dry Mass of 10 Plants After One Week (g)	Change in Dry Mass of 10 Plants Over One Week (g)
I	None	14.8		
II	Light		32.8	+18
III	Dark		11.7	-3.1

Thirty corn seedlings of equal size were randomly assigned to one of three treatment groups. At the beginning of the experiment, the plants in group I were dried and the mass was determined. The plants in group II were maintained in light for a week. The plants in group III were maintained in the dark for a week. All conditions, other than light, were the same for groups II and III. At the end of the week, the plants in groups II and III were dried and the mass was determined. The experimental results are provided in the table.

(a) To explain the increase in mass of the light-grown plants, **identify** ONE inorganic source of new plant mass and **connect it** to the cellular process underlying the increase in mass.

(b) To explain the decrease in mass of the dark-grown plants, **identify** the overall chemical reaction that is occurring in the plant cells and **connect** it to the cellular process underlying the decrease in mass.

23.

According to the chemiosmotic model proposed by Peter Mitchell in 1961, an electrochemical gradient is linked to the synthesis of ATP in mitochondria. Construct an explanation of the chemiosmotic model by doing each of the following.

(a) **Make** a claim about the role of the inner mitochondrial membrane in ATP synthesis.

(b) **Present** ONE piece of evidence that supports the role you proposed in part (a).

(c) **Provide** reasoning to explain how the evidence you presented in part (b) supports the claim you made in part (a).